ENERGY EFFICIENT ICT

UNIVERSITY OF CAMBRIDGE

FACILITATING THE FABRICATION OF METALLIC/ SUPERCONDUCTOR HETEROSTRUCTURES

Royce's Sputter Deposition tool – based at the University of Cambridge – has been used to fabricate multi-layered superconductor/magnetic materials for ferromagnetic resonance experiments, resulting in a paper in *Nature Materials*.

Photo courtesy of Juliet Thompson

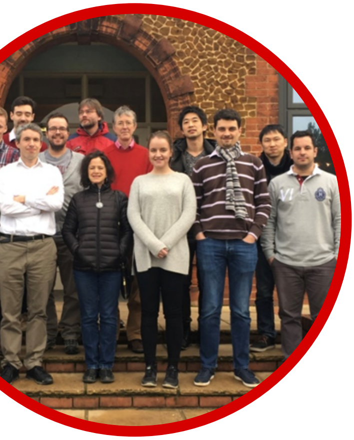
Logic processing based on the spin of an electron (spintronics) can be faster than the conventional charge-based equivalent in semiconductor transistor technologies. However, generating and propagating spin currents is not low power because large charge currents are required at device inputs. Conventional superconductors cannot offer a solution since the pairs of electrons which carry charge have antiparallel spins and so supercurrents carry charge but not spin. However, at the interface between a superconductor and an inhomogeneous ferromagnet, a team at the University of Cambridge discovered a way to generate electron pairs with parallel rather than antiparallel spins ("triplet Cooper pairs"). Triplet supercurrents carry spin in addition to charge and so could potentially be used in spintronics to create highly energy-efficient logic. The Cambridge team have since collaborated to pursue further understanding of the fundamental properties of this new superconducting state and to explore the possibility of superconducting spintronic logic.

THE CHALLENGE

Triplet supercurrents have previously been observed within Josephson junctions involving metallic ferromagnet spacers. In the Cambridge team's 2018 study, ferromagnetic spin sink layers with strong spin–orbit coupling were layered alongside a superconducting material to study the effect of the injection of a pure spin current from a precessing ferromagnet into adjacent non-magnetic materials. A variety of mechanisms for generating triplet states had been proposed, but direct measurement of triplet spin transport through singlet superconductors had yet to be achieved.

ROYCE SUPPORT

Royce equipment was used to grow the range of heterostructures required for the study by sputtering metals in an ultra-high-vacuum chamber to create the Josephson junctions of superconducting/ferromagnetic layers. The wide range of metal targets available from the Royce instrument allowed varying heterostructures and alloy mixtures to be fabricated into precise layers using copper, tantalum, tungsten, platinum, iron, manganese, holmium, and niobium to nanometre precision. The high-quality and internally consistent suite of materials produced allowed the study to robustly compare results obtained between the different materials. The results have shown that within the range of heterostructures produced, the induced spin currents are substantially larger in the superconducting state compared with the normal state.



"Spin currents are central to the technology field of spintronics which uses them to process information in circuits. However, generating and propagating spin currents requires large charge currents at device inputs, which limits the efficiency of spintronic circuits. By applying a microwave field to a magnet/superconductor multilayer, the magnetic layer emits a spin current into the superconductor which is blocked below the superconducting temperature. However, our exciting – unexpected - discovery was that by adding a layer of platinum to the superconductor, the spin current in the superconducting state is enhanced above the normal state, demonstrating dissipation-free spin-currents."

Professor Jason Robinson | Materials Physics
University of Cambridge

Although further detailed theoretical work is required to explain the observed results, the measurements of these novel materials have demonstrated that the spin currents cannot be carried by quasiparticles and are most likely carried by spin-triplet pairs, thereby providing evidence for spin-polarized supercurrents in superconductors and opening up further avenues in fundamental materials research. The resulting research paper has been accessed over 5,000 times since publication, and has already resulted in nearly 40 citations. Use of the Royce tool was instrumental in providing precise control over the deposition of the materials in the heterostructure, to nanometre level. This is a fundamental materials discovery with strong potential to improve the energy efficiency of a range of devices.